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(54) IMPROVEMENTS IN OR RELATING TO ELECTROLUMINESCENT DEVICES AND THEIR MANUFACTURE

(71) We, THE GENERAL ELECTRIC COMPANY LIMITED, of 1 Stanhope Gate, London, W1A 1EH, a British Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to electroluminescent display devices of the type consisting of a panel which comprises essentially, supported on a light-transmissive substrate, a layer of electroluminescent phosphor, two electrodes in contact with the phosphor layer, and contacts for connection of the electrodes to a source of electric current supply for the application of an operating voltage between the electrodes. The invention is more particularly, but not exclusively, concerned with devices of this type which are adapted for operation by the application of a unidirectional voltage between the electrodes. The invention also relates to methods of manufacturing the devices.

In prior art electroluminescent panel of the type referred to, the phosphor layer may be sandwiched between a front electrode and a back electrode, the front electrode being light-transmissive and usually in the form of a transparent electrically conductive coating on the substrate, and all parts of the phosphor layer disposed between the two electrodes being excited to luminescence by the applied voltage. Alternatively, the electrodes may be located on the same side of the phosphor layer, usually side by side with only a small gap between them: in this case only the portion of the phosphor layer in the gap between the electrodes is excited to luminescence in operation.

A panel of either of the above forms may comprise a single electroluminescent cell, or may consist of an array of light-emitting cells capable of being independently energised singly or in various combinations, for the production of selected displays. In panels of the kind consisting of an array, as manufactured hitherto, the individual cells have been delineated by forming one or both of the electrodes, of the phosphor layer, in a plurality of sections. For example, where the phosphor layer is sandwiched between two electrodes, an array of square or rectangular cells may be produced by making each of the electrodes, on either side of a continuous phosphor layer, in the form of a series of parallel stripes, the two series of stripes being orthogonal to one another.

A problem which arises in operation of electroluminescent panels of the type referred to, and which is particularly evident in panels comprising a multiplicity of electroluminescent cells, is the occurrence of leakage current at the edges of the light-emitting regions. Such leakage current can cause overheating of the panel and non-uniformity of the light emitted from each cell, may cause interference in complex arrays, and may also cause phosphor adjacent to the cells to luminesce to an undesirable degree in all but the simplest displays.

It is an object of the present invention to provide an improved form of construction, and method of manufacture, of electroluminescent panels of the type referred to, whereby the light-emitting regions of the panel can be delineated in a novel manner and the occurrence of edge leakage current in such regions, in operation of the panel, can be reduced or prevented, and whereby in addition the useful life of the device can be prolonged.

According to the invention, in an electroluminescent display device of the type comprising, supported on a light-transmissive substrate, a layer of electroluminescent phosphor and two electrodes in contact with said phosphor layer, with contacts for connection of

the said electrodes to a source of electric current supply for the application of an operating voltage between the electrodes, the phosphor layer is continuous but does not extend to the edges of the substrate, means are included for electrically insulating intended passive portions, as hereinafter defined, of the phosphor layer from at least one of the electrodes, the phosphor layer is wholly enclosed within an evacuated or dry gas-filled encapsulating dome of insulating material impervious to moisture which dome is sealed to the substrate, and the said contacts for both electrodes are located adjacent to the edges of the substrate and at least partly outside the said dome.

The phrase "intended passive portions of the phosphor layer" is to be understood to mean those portions of the phosphor layer which are not required to emit light in operation of the device.

It will also be understood that either or both of the electrodes may be formed in a plurality of separate sections, each including a lead portion to a contact located adjacent to the edge of the substrate, and that the term "electrode" as used herein accordingly includes a multi-section electrode.

An electroluminescent panel in accordance with the invention may be constituted by a single cell. However, the invention is especially applicable to multiple cell panels, which may consist of geometrical arrays of light-emitting squares, rectangles, circles, or any other desired shapes, or of alpha-numeric displays.

The means for insulating intended passive portions of the phosphor layer from an electrode suitably consists of a layer of insulating material corresponding in area and location to the said portions of the phosphor layer.

In one form of the invention, hereinafter referred to as a "sandwich panel", the phosphor layer is sandwiched between a light-transmissive front electrode and an opaque metal back electrode, and the said insulating means preferably consists of an insulating layer in contact with those portions of the front electrode which correspond to the required passive portions of the phosphor layer. Since this insulation of portions of the phosphor layer from one of the electrodes effectively prevents the passage of current through those portions of phosphor, the light-emitting areas of the panel are delineated by the insulating layer, and hence it is not necessary for the electrodes to be formed in a particular configuration for delineating the light-emitting areas. It is usually convenient to form the front electrode in sections which are overlapped by portions of the insulating layer, the areas of overlap corresponding to the required passive portions of the panel, and to form the back electrode as a continuous metal layer overlying all or part of the phosphor layer, both the front electrode sections and the back electrode being connected to respective contact areas adjacent to the edges of the substrate. The presence of the insulating layer has the effect of reducing or preventing the occurrence of leakage current at the edges of the light-emitting areas in operation of the device.

The preferred method of manufacturing an electroluminescent device in accordance with the invention, in the form of a sandwich panel, thus includes the steps of forming on a light-transmissive substrate a front electrode consisting of a light-transmissive, electrically conductive coating, forming contact areas adjacent to the edges of the substrate, a first contact area or group of contact areas being formed on the conductive coating and a second contact area or group of contact areas being formed either directly on the substrate surface or on a separate portion or portions of the conductive coating, and insulated from the first contact area or areas, depositing a layer of insulating material upon at least the portion or portions of the said conductive coating corresponding to the intended passive portions of the phosphor layer, depositing a continuous phosphor layer upon the said insulating layer and upon at least part of the light-transmissive conductive coating, depositing a continuous metal layer, for forming the back electrode, upon at least part of the phosphor layer and extending on to the said second contact area or group of contact areas, and placing an encapsulating dome over the back electrode and phosphor layer, so as to enclose the whole of the phosphor layer, the said dome being sealed to the substrate and contact areas.

The substrate is suitably of glass, on which the front electrode is preferably formed by deposition of a transparent coating of tin oxide, in well known manner. For the manufacture of a multiple cell panel parts of the conductive coating are removed, for example by etching, to leave the required number of separate electrode sections, each of which is subsequently provided with an edge contact area, and the insulating layer will also be formed in a plurality of sections, as required for delineating the light-emitting areas of the panel. The contact areas and back electrode may be of known form: thus the contact areas may be formed of any conducing material which adheres well to the substrate and to the conducting coating thereon, evaporated aluminium, for example, being a suitable material in the case of a tin oxide coated glass substrate. The back electrode may be of copper, silver or aluminium, and may be applied by evaporation, painting or spraying.

In another form of the invention, hereinafter referred to as a "gap-cell panel", both

electrodes are disposed on the same side of the phosphor layer, adjacent to one another but with a gap between them, and the intended passive portions of the phosphor layer located in the gap between the electrodes are electrically insulated from both of the electrodes. To achieve electrical insulation, a layer of insulating material is interposed between part of the phosphor layer and the electrodes so as to fill the parts of the said gap corresponding to the required passive portions of the phosphor layer and to cover the portions of the electrodes on each side of such parts of the gap. Thus the light-emitting areas of the gap between the electrodes are delineated by the insulating layer. If desired, each of the electrodes may be divided into sections so as to form a plurality of gap-cells, the light-emitting areas of each of which are delineated by the insulating layer.

Thus one method of manufacturing an electroluminescent device in accordance with the invention, in the form of a gap-cell panel, includes the steps of forming on a light-transmissive substrate a pair of electrodes, both electrodes being either continuous or divided into sections, forming contact areas adjacent to the edges of the substrate, upon or connected to each electrode, or each said section, depositing a layer of insulating material upon the portions of both electrodes lying on each side of the intended passive portions of the gap between the electrodes and filling the said portions of the gap with the insulating material, depositing a continuous layer of phosphor over at least part of the assembly of electrodes and insulating layer so as to cover the required light-emitting areas of the gap between the electrodes and the portions of the electrodes adjacent thereto, and placing an encapsulating dome over the phosphor layer, so as to cover the whole of the phosphor layer, the said dome being sealed to the substrate and contact areas. When this method is employed for the manufacture of a gap-cell panel, the electrode may conveniently be in the form of a conductive coating on the substrate, for example tin oxide on a glass substrate, etched to the desired shape and dimensions in known manner.

An alternative method of manufacturing a gap-cell panel in accordance with the invention includes the steps of depositing a continuous layer of phosphor on the requisite area of a light-transmissive substrate, depositing a layer of insulating material upon those portions of the phosphor layer corresponding to the intended passive portions of the gap-cell or cells to be formed, forming a pair of electrodes, each continuous or in sections, adjacent to one another in the required positions on the insulating layer and phosphor layer, forming contact areas adjacent to the edges of the substrate, upon or connected to each electrode or each said section, and placing an encapsulating dome over the assembly so as to cover the whole of the phosphor layer, the said dome being sealed to the substrate and contact areas. In this case the electrodes may be of metal, and are suitably formed by vapour deposition through an appropriate mask.

Suitable materials for use for forming the insulating layer, in both the forms of the invention described above, include silica, and various photoresists. The layer may be deposited by any convenient method, for example by evaporation, sputtering as in the case of silica for instance, painting, spraying or spreading; photoresists are preferably applied by spinning or spraying. When using any of these processes, the panel will be suitably masked to obtain deposition of the insulating material only on the requisite areas.

An electroluminescent device in accordance with the invention may be designed for excitation by an alternating voltage, or by a continuous or pulsed unidirectional voltage. The phosphor layer, which may be in the form of either a powder coating deposited by painting or spraying, or a thin film deposited by vacuum evaporation, preferably consists of zinc sulphide activated by copper and manganese; if the device is to be operated by a unidirectional voltage, the phosphor is rendered conducting under direct current conditions by washing with a metallic salt solution such as an aqueous solution of copper nitrate.

The encapsulating dome in which the phosphor layer is enclosed is formed of material which is impervious to moisture, suitably glass or synthetic plastic material, and is sealed directly to coated or uncoated parts of the substrate and to the contact areas formed adjacent to the edges of the substrate, by means of a suitable adhesive, sufficient contact areas for attachment to connecting leads being retained outside the dome. The useful life of the electroluminescent panel is prolonged by encapsulation of the phosphor layer, and the form of encapsulation employed in accordance with the invention, in which the substrate itself constitutes one encapsulating face, is advantageous since complete envelopment of the device is thereby avoided and at least parts of the contacts on the edge regions of the substrate remain exposed and thus readily accessible. In order to increase the life of the device still further, the encapsulating dome is preferably either filled with an inert gas, possibly containing a small proportion of an additional gas in accordance with a feature of the invention to be described below, or evacuated through a pumping stem attached to the dome; preferably also the dome contains a getter capable of absorbing water vapour, for example

a desiccant such as magnesium perchlorate or a suitable molecular sieve.

According to a feature of the invention, in an encapsulated electroluminescent device of either of the forms described above, incorporating a powder layer of zinc sulphide or other phosphor which is an n-type semiconductor, such as zinc selenide, cadmium sulphide or cadmium selenide, the encapsulating dome is preferably filled with a dry atmosphere consisting substantially of a mixture of an inert gas and a gas which, when adsorbed at the surface of the said phosphor layer, is capable of accepting negative electric charges transferred thereto from the phosphor layer.

The presence of a suitable negative charge-accepting gas in the encapsulating atmosphere of an n-type phosphor powder layer is advantageous in that as a result of the transfer of negative charges from the phosphor to the gas, the electric current flowing through the device in operation at a given voltage is reduced, without a significant reduction in the visible light output occurring. It is essential that the gas mixture within the encapsulating dome is dry since, apart from the fact that moisture has a deleterious effect on the life of the device, a transfer of negative charges from water vapour to the phosphor layer tends to take place, so that the presence of water vapour might nullify the effect of the charge-accepting gas. In order to ensure that the atmosphere within the dome is maintained in a dry state, the dome preferably contains a getter as aforesaid.

It will be understood that the term "inert gas", as used herein, means a gas, such as nitrogen or argon, which has no chemical or physical action on the phosphor or other materials with which it comes into contact in the device. When a charge-accepting gas is included in the encapsulating atmosphere this must also, of course, be one which has no deleterious effect on the phosphor or other materials present, and is preferably oxygen, although other suitable gases such as ozone can be used. Small amounts of incidental gaseous impurities, including binder and solvent vapours from the phosphor layer, which do not adversely affect the beneficial action of the charge-accepting gas may also be present. The gas mixture within the encapsulation dome may suitably be under normal atmospheric pressure, but higher or lower pressures may be employed if desired.

Any electrodes or insulating material overlying the phosphor layer or parts thereof should possess sufficient porosity to permit diffusion of the charge-accepting gas through such electrodes or material to the phosphor layer, when such gas is present. In addition, some diffusion of the gas from exposed edge portions of the phosphor layer into covered parts of the said layer may take place.

The suitable relative proportions of inert gas and charge-accepting gas in the encapsulation atmosphere will vary with different charge-accepting gases and with different phosphors. For example, in the case of a zinc sulphide powder panel encapsulated in a mixture of nitrogen and oxygen, the proportion of oxygen in the said mixture may be in the range of 50 p.p.m. to about 20% by volume: thus to give an oxygen content at the upper end of this range, dry clean air may be used, the minor amounts of carbon dioxide and other inert gases in the air being immaterial. The inclusion of a proportion of oxygen in this range in the encapsulation atmosphere results in a reduction in the current passing through the device in operation, as compared with the current passed, at the same voltage, when the phosphor layer is encapsulated in pure nitrogen or in vacuum. The optimum proportion of charge-accepting gas also depends upon the relative proportions of active (that is to say required light-emitting) and passive (non-emitting) phosphor areas and encapsulated volume; for example, in a zinc sulphide panel as aforesaid in which the ratio of passive phosphor area to active phosphor area is 10:1, an oxygen content of 1% to 2% by volume is preferred. In a specific example of a zinc sulphide panel, having an active phosphor area of 0.2 cm^2 and a passive area of 2.0 cm^2, and an encapsulated volume of approximately 2.0 cm^3, we have found that the current passing through the panel in operation decreases with increasing oxygen concentration up to about 2% by volume, little further decrease in current occurring at higher oxygen concentrations. In the range of oxygen contents from 2% down to 50 p.p.m., the increase in current is accompanied by an increase in the brightness of the light emitted by the phosphor, but also by a reduction in efficiency, especially at oxygen concentrations below about 1%. The oxygen concentration employed in a particular device will therefore depend upon the relative importance of the requirements in respect of luminance and efficiency, in addition to the other factors mentioned above. Higher proportions of oxygen will be required for higher specific active phosphor surface areas.

In the manufacture of a device having a gas-filled encapsulation dome, the required gas mixture may be introduced into the dome, after the latter has been sealed to the substrate, through a pumping stem attached to the dome, the stem being subsequently sealed off.

If desired, a device in accordance with the invention may be heat treated to remove water vapour and any other volatile substances which may be present, for example

in the phosphor layer, immediately prior to encapsulation, and in some cases a heat treatment subsequent to encapsulation may be beneficial.

The device is usually subjected to an electrical forming process, to develop its electroluminescent properties and to increase its electrical resistance. This treatment consists in passing an electric current through the device, at a suitable voltage and power dissipation depending on the size of the area to be formed and on the nature of the prior treatment of the panel, in particular on the extent to which the panel has been heat treated. Forming is usually effected at voltages in the approximate range of 6 to 100 volts, and is preferably carried out in two stages, the first forming stage being carried out at a relatively low voltage, for example in the range of 6 to 10 volts, and the voltage then being increased gradually to the desired maximum value, over a period of time depending on the area of the panel. For example, in the case of a small panel, of area approximately half an inch square, the forming voltage may be raised from 10 to 100 volts in one hour, the voltage being increased more slowly the larger the area of the panel.

Forming may be carried out either before or after encapsulation, provided that if the encapsulation atmosphere includes a charge-accepting gas, forming is effected in an atmosphere containing the charge-accepting gas to be employed, furthermore where a charge-accepting gas is used, if forming is carried out after encapsulation the proportion of the charge-accepting gas initially introduced into the encapsulating dome should be somewhat greater than the proportion ultimately required in the completed device, since some of this gas will be absorbed by the phosphor layer, and possibly by other components of the device, during the forming process. For example, to obtain a final concentration of 1% to 2% by volume of oxygen, the proportion of oxygen in the gas mixture initially introduced into the dome is about 2% to 3% by volume.

Some specific methods which we have employed for the manufacture of electroluminescent panels in accordance with the invention will now be described in the following examples, with reference to the accompanying diagrammatic drawings, in which

Figures 1, 3, 5, 7, 9 and 11 are plan views of a sandwich panel at successive stages in its manufacture,

Figures 2, 4, 6, 8, 10 and 12 show the respective corresponding stages in sectional elevation, the sections being drawn along the lines II—II, IV—IV, VI—VI, VIII—VIII, X—X and XII—XII in Figures 1, 3, 5, 7, 9 and 11 respectively, and

Figures 13, 14, 15 and 16 show some of the stages in the manufacture of a gap-cell panel, Figures 13 and 15 being plan views and Figures 14 and 16 sections drawn on the lines XIV—XIV and XVI—XVI in Figures 13 and 15 respectively.

In the drawings, the various layers of materials are shown in exaggerated thickness, for clarity.

Example 1.

In the manufacture of the sandwich panel, illustrated in Figures 1 to 12 inclusive, a glass substrate 1 is coated in known manner with a transparent layer of tin oxide, parts of which are then removed by etching to leave two strips 2 constituting separate sections of the front electrode, as shown in Figures 1 and 2: the etching is carried out by coating the appropriate portions of the tin oxide layer with a zinc powder-water paste, drying, and adding 50% aqueous hydrochloric acid, thus causing the evolution of nascent hydrogen which removes the underlying tin oxide. Figures 3 and 4 show the contact pads 3 and 4, which are formed by the deposition of evaporated aluminium, the pads 3 being formed on the front electrode strips and pads 4 on uncoated parts of the substrate. An insulating layer is then deposited in two strips 5, lying orthogonally to the front electrode strips, and extending on to the contact pads 4, as shown in Figures 5 and 6. The insulating material employed is preferably a photoresist, which is deposited by spinning or spraying: the positive resist sold under the Registered Trade Mark "Shipley 1350H", or the negative resist sold under the Registered Trade Mark "KMER", have been found to be particularly suitable for this purpose. The photoresist is then heat treated to render it insoluble in the binder liquid employed in the phosphor layer subsequently applied: the heat treatment typically consists in heating the panel at 200°C for 2 hours in air.

A layer of phosphor powder 6, as shown in Figures 7 and 8, consisting of copper-coated particles of zinc sulphide activated by copper and manganese, is then applied by painting on a suspension of the powder in a suitable binder solution, such as a solution of polymethylmethacrylate in xylene, and the solvent is removed by drying at a suitable temperature in the range of 100°C to 130°C, for a few minutes. The phosphor layer is typically 50 microns thick, and the step between the phosphor layer and the contact pads 4 may be filled with a paint or epoxy resin loaded with fine metal powder, as shown at 7 (Figure 8). It will be seen that the phosphor layer overlaps the insulating strips 5 and overlies the portions 8 of the front electrode strips, visible in Figure 5 between the insulating strips. The active areas of the phosphor layer (that is to say the light-emitting areas in operation of the device)

will thus correspond to the rectangular regions 8, delineated by the front electrode and the insulating layer.

The back electrode is next deposited on the phosphor layer, in the form of an evaporated coating of aluminium. This coating, shown at 9 in Figures 9 and 10, covers a sufficient width of the phosphor layer to ensure that the back electrode overlies the intended active areas 8, and extends on to the contact pads 4, these extensions thus providing leads for connection of the back electrode to the contacts and hence to an electric current supply. The step of forming the back electrode is preferably carried out in an evacuated bell jar. The panel is then heated at a suitable temperature, for example about 100°C, to expel volatiles, especially water vapour, and finally a glass dome 10, shown in Figures 11 and 12, is placed over the central region of the panel so as to cover the phosphor layer and the back electrode, a getter in the form of 1/16 inch diameter pellets 11 of a molecular sieve material, suitably BDH Molecular Sieve Type 5A, being inserted within the dome. The edge of the dome is sealed to the contact pads 4, the front electrode strips 2, and the exposed portions of the substrate 1, by means of an epoxy resin adhesive, as shown at 12. The panel may be surrounded by a dry inert gas atmosphere during the encapsulation step, or alternatively the dome may be provided with a pumping stem (not shown) through which the dome is evacuated, or filled with dry nitrogen or argon, after sealing.

After encapsulation, the device is subjected to a forming process consisting in the initial application of a unidirectional voltage of 10 volts between the electrodes, at a power dissipation of 1 to 2 watts, for a few minutes, and then gradually increasing the applied voltage to 100 volts, this treatment resulting in the emission of light from the whole of the active areas.

Example 2.

The method of manufacture described in Example 1 with reference to Figures 1 to 12 of the drawings is modified by filling the encapsulating dome with a mixture of dry nitrogen and dry oxygen. For a panel having an active phosphor area of 0.2 cm^2 and a passive area of 2.0 cm^2, and an encapsulated volume of approximately 2 cm^3, the proportion of oxygen initially introduced into the dome is slightly less than 2% by volume of the gas mixture, to give an oxygen concentration of approximately 1% by volume after a forming process carried out as described in Example 1, in which the raising of the applied voltage from 10 to 100 volts is effected over a period of one hour. Whereas, in the operation of a similar device having a filling of pure nitrogen in the encapsulating dome, the efficiency has been found to fall while the current through the device remains at the relatively high value of approximately 20 mA/cm^2 at 100 volts, the inclusion of 1% of oxygen in the encapsulating atmosphere, in accordance with this example, has been found to reduce the current to 5 mA/cm^2 without falling efficiency, but with some reduction in the brightness of emission.

Example 3.

In the manufacture of a gap-cell panel, as shown in Figures 13 to 16 of the drawings, tin oxide electrodes 13 and 14 are formed on a glass substrate 12 by the method described in Example 1: each electrode consists of two sections, 13a, 13b and 14a, 14b, with gaps 15a, 15b between them. Contact pads 16 are then formed on the outer end regions of the electrode sections, by the deposition of evaporated aluminium. Two strips of insulating material 17, 18 are then deposited across the two pairs of electrode sections, filling parts of the gaps 15a and 15b respectively, as shown in Figures 13 and 14: the insulating strips are formed in the manner described in Example 1. A continuous phosphor layer 19, similar to the phosphor layer described in Example 1, is then deposited over parts of the electrodes and insulating strips as shown in Figures 15 and 16: the light-emitting regions formed by this arrangement are shown by the stippled areas 20. The manufacture of the panel is completed by heat treatment, encapsulation and forming, all as described in Example 1, if desired with the inclusion of oxygen in the encapsulation atmosphere as described in Example 2; the encapsulation dome and getter employed are similar to those shown in Figure 12.

In each of the above specific examples, the manfacture of a panel comprising only two active areas is described, in the interests of simplicity and clarity of the drawings; however, panels having any desired number of active areas, and in the case of a sandwich panel as described in Examples 1 and 2, active areas of any desired shapes, can be prepared by the methods described.

WHAT WE CLAIM IS:—

1. An electroluminescent display device of the type comprising, supported on a light-transmissive substrate, a layer of electroluminescent phosphor and two electrodes in contact with said phosphor layer, with contacts for connection of the said electrodes to a source of electric current supply for the application of an operating voltage between the electrodes, wherein the phosphor layer is continuous but does not extend to the edges of the substrate, means are included for electrically insulating intended passive portions as hereinbefore defined, of the phosphor layer

from at least one of the electrodes, the phosphor layer is wholly enclosed within an evacuated or dry gas-filled encapsulating dome of insulating material impervious to moisture, which dome is sealed to the substrate, and the said contacts for both electrodes are located adjacent to the edges of the substrate and at least partly outside the said dome.

2. A device according to Claim 1, wherein the said electrically insulating means consists of a layer of insulating material corresponding in area and location to the intended passive portions of the phosphor layer.

3. A device according to Claim 2, wherein the phosphor layer is sandwiched between a light-transmissive front electrode and an opaque metal back electrode, and the said layer of insulating material is in contact with those portions of the front electrode which correspond to the intended passive portions of the phosphor layer.

4. A device according to Claim 3, wherein the said front electrode is formed in sections which are overlapped by portions of the insulating layer, the areas of overlap corresponding to the intended passive portions of the phosphor layer, and the said back electrode is formed as a continuous metal layer overlying all or part of the phosphor layer.

5. A method of manufacturing a device according to Claim 3 or 4, which includes the steps of forming on a light-transmissive substrate a front electrode consisting of a light-transmissive electrically conductive coating, forming contact areas adjacent to the edges of the substrate, a first contact area or group of contact areas being formed on the said conductive coating and a second contact area or group of contact areas being formed either directly on the substrate surface or on a separate portion or portions of the conductive coating, and insulated from the said first contact area or areas, depositing a layer of insulating material upon the portion or portions of the said conductive coating corresponding to the intended passive portions of the phosphor layer, depositing a continuous phosphor layer upon the said insulating layer and upon at least part of the said light-transmissive conductive coating, depositing the back electrode in the form of a continuous metal layer upon at least part of the phosphor layer and extending on to the said second contact area or group of contact areas, and placing an encapsulating dome over the back electrode and phosphor layer, so as to enclose the whole of the phosphor layer, the said dome being sealed to the substrate and contact areas.

6. A device according to Claim 2, wherein both electrodes are disposed on the same side of the phosphor layer, adjacent to one another but with a gap between them, and the intended passive portions of the phosphor layer located in the gap between the electrodes are electrically insulated from both of the electrodes by means of a layer of insulating material interposed between part of the phosphor layer and the electrodes so as to fill the parts of the said gap corresponding to the intended passive portions of the phosphor layer and to cover the portions of the electrodes on each side of such parts of the gap.

7. A device according to Claim 6, wherein each of the electrodes is divided into sections so as to form a plurality of gap-cells.

8. A method of manufacturing a device according to Claim 6 or 7, which includes the steps of forming on a light-transmissive substrate a pair of electrodes, both electrodes being either continuous or divided into sections, forming contact areas adjacent to the edges of the substrate, upon or connected to each electrode or each said section, depositing a layer of insulating material upon the portions of both electrodes lying on each side of the intended passive portions of the gap between the electrodes and filling the said portions of the gap with the insulating material, depositing a continuous layer of phosphor over at least part of the assembly of electrodes and insulating layer so as to cover the required light-emitting areas of the gap between the electrodes and the portions of the electrodes adjacent thereto, and placing an encapsulating dome over the phosphor layer, so as to cover the whole thereof, the said dome being sealed to the substrate and the contact areas.

9. A method of manufacturing a device according to Claim 6 or 7, which includes the steps of depositing a continuous layer of phosphor upon a desired area of a light-transmissive substrate, depositing a layer of insulating material upon those portions of the phosphor layer corresponding to the intended passive portions of the desired gap-cell or cells comprising both electrodes and the gap between them, forming a pair of electrodes, each continuous or in sections, adjacent to one another in the required positions on the insulating layer and phosphor layer, forming contact areas adjacent to the edges of the substrate, upon or connected to each electrode or each said section, and placing an encapsulating dome over the assembly so as to cover the whole of the phosphor layer, the said dome being sealed to the substrate and contact areas.

10. A device according to any one of the preceding Claims 2, 3, 4, 6 or 7, wherein the said insulating material consists of silica or a photoresist.

11. A device according to any one of the preceding Claims 1 to 4, 6, 7 or 10, wherein the phosphor layer consists of a powder coating or a film of zinc sulphide activated by copper and manganese.

12. A device according to any one of the preceding Claims 1 to 4, 6, 7, 10 or 11, wherein the encapsulating dome is formed of glass or synthetic plastic material.

13. A device according to any one of the preceding Claims 1 to 4, 6, 7, 10, 11 or 12, wherein the encapsulating dome is filled with an inert gas or is evacuated.

14. A device according to any one of the preceding Claims 1 to 4, 6, 7, 10 to 13, wherein the encapsulating dome contains a getter capable of absorbing water vapour.

15. A device according to any one of the preceding Claims 1 to 4, 6, 7, 10, 11 or 12, wherein the phosphor layer is a powder layer of a phosphor which is an n-type semiconductor, and the encapsulating dome is filled with a dry atmosphere consisting substantially of a mixture of an inert gas and a gas which, when adsorbed at the surface of the said phosphor layer, is capable of accepting negative electric charges transferred thereto from the phosphor layer, the said dome also containing a getter capable of absorbing water vapour.

16. A device according to Claim 15, wherein the said charge-accepting gas is oxygen.

17. A device according to Claim 16, wherein the phosphor layer consists of a zinc sulphide phosphor powder and the atmosphere within the encapsulating dome consists substantially of a mixture of nitrogen and oxygen in which the proportion of oxygen is in the range of 50 parts per million to 20 percent, by volume.

18. A device according to Claim 17, wherein the ratio of passive phosphor area to active phosphor area is 10:1, and the proportion of oxygen in said gas mixture is 1 percent to 2 percent by volume.

19. A device according to any one of the preceding Claims 15 to 18, wherein the electrodes and insulating material overlying the phosphor layer or parts thereof possess sufficient porosity to permit diffusion of the said charge-accepting gas through such electrodes or material to the phosphor layer.

20. A method of manufacturing a device according to any one of the preceding claims 13, 15 to 19, wherein the required gas filling is introduced into the encapsulation dome, or the dome is evacuated, after the dome has been sealed to the substrate, through a pumping stem attached to the dome, said stem subsequently being sealed off.

21. A method of manufacturing a device according to any one of the preceding Claims 1 to 4, 6, 7, 10 to 19, wherein the device is heat treated immediately prior to encapsulation, to remove water vapour and other volatile substances present.

22. A method of manufacturing a device according to any one of the preceding Claims 1 to 4, 6, 7, 10 to 19, wherein the device is subjected to heat treatment subsequently to encapsulation.

23. A method of manufacturing a device according to any one of the preceding Claims 1 to 4, 6, 7, 10 to 19, wherein the device is subjected to an electrical forming treatment which consists in passing an electric current through the device at voltages in the range of 6 to 100 volts.

24. A method according to Claim 23, wherein the said forming treatment is carried out in two stages, the first stage being carried out at 6 to 10 volts, and the second stage consisting in increasing the voltage gradually to a desired maximum value not exceeding 100 volts.

25. A method according to Claim 23 or 24 wherein, for the manufacture of a device according to any one of the preceding Claims 15 to 19, forming is carried out prior to encapsulation and in an atmosphere containing the said charge-accepting gas.

26. A method according to Claim 23 or 24 wherein, for the manufacture of a device according to any one of the preceding Claims 15 to 19, forming is carried out subsequently to encapsulation, and the gas mixture initially introduced into the encapsulation dome includes a proportion of the said charge-accepting gas which is larger than the proportion ultimately required in the completed device.

27. An electroluminescent display device according to Claim 1, substantially as hereinbefore described in any one of the Examples 1 to 3, with reference to Figures 1 to 12 inclusive, or Figures 13 to 16 inclusive, of the accompanying drawings.

28. A method of manufacturing an electroluminescent display device according to Claim 1, carried out substantially as hereinbefore described in any one of the Examples 1 to 3, with reference to Figures 1 to 12 inclusive, or Figures 13 to 16 inclusive, of the accompanying drawings.

For the Applicants,
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Chartered Patent Agent.

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1366678 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

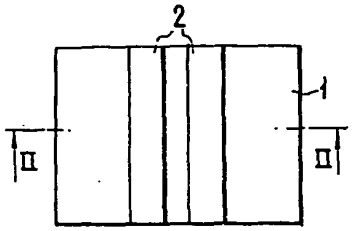


Fig.1

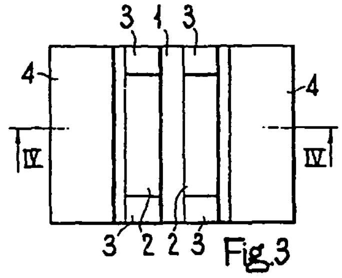


Fig.3

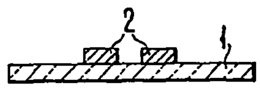
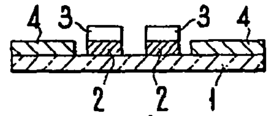


Fig.2



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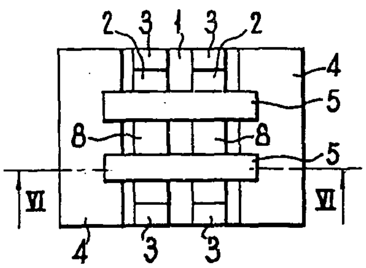

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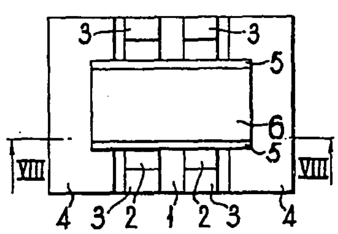
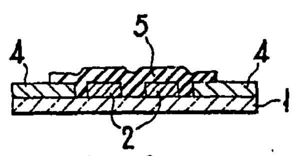


Fig.7



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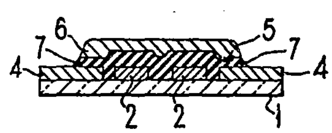


Fig.8

1366678 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

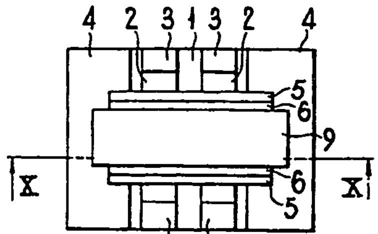


Fig.9

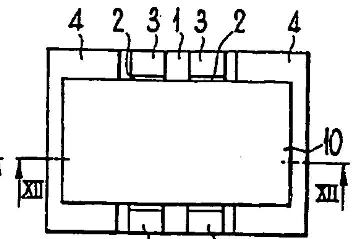


Fig.11

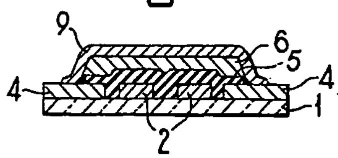
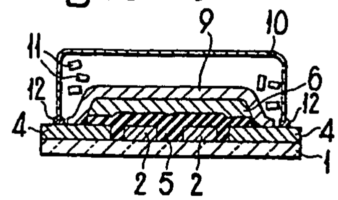


Fig.10



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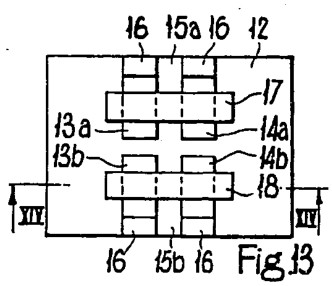

Fig.13

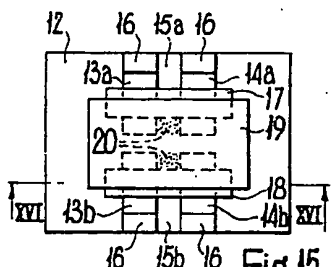

Fig.15

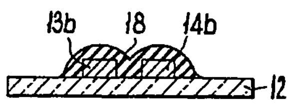

Fig.14

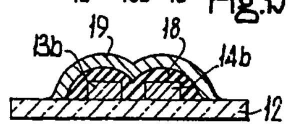

Fig.16